BREAKDOWN AND ROOT CAUSE ANALYSIS OF CRITICAL MACHINE- A CASE STUDY

Manoj M[1], Dr.G Mallesh[2]
[1]*P.G Student, Department of Mechanical Engg. , SJCE- Mysore, India*
[2]*Associate Professor, Department of Mechanical Engg. SJCE-Mysore, India*

ABSTRACT

Maintenance can be defined as actions necessary for retaining or restoring a piece of equipment, machine or system to the specified operating conditions to achieve its maximum useful life. Maintenance ensures that production plant and equipments are available for production with minimum cost and wastage. Any organization regardless of the size, technology, products and services must have a clear cut maintenance policy to meet its individual needs. Preventive maintenance is a set of activities that are performed on plant, equipment, machinery, and systems before the occurrence of a failure in order to protect them and to prevent or eliminate any degradation in their operating conditions.

Predictive maintenance is the complement of preventive maintenance. Predictive maintenance determines equipment status before a breakdown occurs. Production may be stopped due to many reasons like breakdown of machine, maintenance work, labour issues, and inventory problems. It is necessary to reduce the breakdown of machine or equipments in the company for the efficient production to meet the demands.

The main objective of this project is to study the breakdown of a critical machine in automotive axle the major breakdowns were observed in Landis threading machine, Hot swage machine and Shot blast machine. Breakdown history of each machine was analyzed form 2010-2014 and noticed that Landis threading machine contribute major loss to the industry, hence detailed study was carried out to minimize loss.

Production process and machine breakdown was studied using different analysis and inspection tools like fish bone diagram, why- why analysis and counter measures to determine the machine availability, machine availability was determined by MTTR and MTBF. Based on the problems root cause analyses were carried out to develop and improve new preventive maintenance schedule and checklist for a machine.

Keywords - Availability, Breakdown, downtime, Preventive Maintenance and Root Cause analysis, Fish bone diagram, Why-why analysis

I. INTRODUCTION

Industries all over the world have entered the era of high technology maintenance management in a desire to minimize down time and penalty costs. The speed, with which technology advances, requires careful management consideration. These advances bring with them new management problems that have not been encountered before and difficulties are being experience in solving them, especially when the cost factor rises continuously at the end of the line. Since no equipment is composed of failure free parts, there will always be downtime due to repairs and maintenance. The more complex a piece of equipment, the longer it takes for the diagnosis and repair of failure. When the repairing or replacing faulty equipment involves an unexpected cause, its unavailability may have even more serious consequences.

As the science and technology gearing day-by-day towards modernization and sophistication, the new incoming production equipments are increasingly becoming complex in their parts/assemblies mechanisms. At the same time, the use of maintenance is getting more and more popularity in the industries because of its outstanding advantages in overcoming the problems related to the equipments.

Machine and equipment breakdowns found in most manufacturing industries in developing countries like India and the adverse effects on the overall performance of the organization ranging from production loss, high production cost, obvious inability to meet production deadlines, poor company's reputation and loss of integrity which invariably reduces the share capital and the ability to compete with similar industries creates a window of research for possible remedies. Machine maintenance is gaining importance in industry because of the need to decrease the possibility of production loss due to machine breakdown schedule preventive maintenance reduces the regular breakdowns and increases the availability of machine .The goal of maintenance is to ensure that the performance of the equipment is satisfactory. The major emphasis of this work will be the development of workable strategies which will drastically reduce or totally eliminate machine and equipment breakdowns in a production line.

A good maintenance system contributes to efficiency, customer service, high quality, safety, on time delivery, and customer satisfaction. For complex mechanical equipment containing N units the optimal model to preventive maintenance cycle policy is proposed to minimize the maintenance cost rate. A conception of the production scheduling and preventive maintenance in industries was taken for the research work. Thus, there is an intense need for manufacturing industries to reduce unexpected breakdowns and remain competitive, and motivating maintenance operations should be integrated into production scheduling models.

II. PROBLEM DEFINITION

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Production process and machine breakdown was studied using different analysis and inspection tools like fish bone diagram, why- why analysis and counter measures to determine the machine availability, machine availability was determined by MTTR and MTBF. Based on the problems root cause analysis were carried out to develop and improve new preventive maintenance schedule and checklist for a machine.

III. OBJECTIVE OF THE PRESENT STUDY

- To increase the availability of a machine
- To reduce the down time of a machine
- To maximize production rate
- To improve new preventive maintenance schedule and checklist

IV. PROCESS STUDY

Process study is the systematic examination of the methods of carrying out activities such as to improve the effective use of resources and to set up standards of performance for the activities carried out. In this project process study has been carried to identify the causes of failure and remedies to overcome these failures without implementing statistical tools.

4.1. Process Study of Hot Swage Machine

Main objective of hot swage machine is to alter the dimension of the component. Hot swaging is a forging process in which the dimensions of an item are altered using dies into which the item is forced. It is a process for precision forming of tubes, bars or wires. One of the characteristics is that the finished shape of the formed work pieces is obtained without, or with only a minimum amount of further final processing by machining.

As a general manufacturing process swaging may be broken up into two categories. The first category of swaging involves extrusion of the work piece, forcing it through a confining die to reduce its diameter, similar to the process of drawing wire. This may also be referred to as "tube swaging." The second category involves two or more dies used to hammer a round work piece into a smaller diameter. This process is usually called "rotary swaging" or "radial forging.

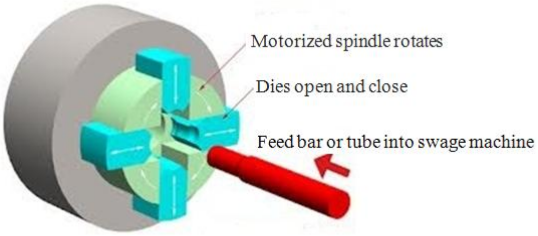

Fig: 1 Hot Swage Process

TABLE 1: Specification of Hot Swage Machine

1	Model number	FVDP
2	Capacity of production	56 swages per shift
3	Machine cycle time	8 minutes
4	1 time finish length	120mm
5	Mass	3200 kg
6	Heating temperature	900°C
7	Heating Time	40 seconds
8	Diameter of die	150 mm- Ashok Leyland, TATA company ,135 mm-china AMW company
9	Component mass	40 kg
10	Hydraulic pressure	50 tons

This machine was subjected to frequent breakdowns due to improper maintenance; hence breakdown analysis was carried out to indentify the specific problem in the machine and process, breakdown data was collected from Jan 2010-Dec 2013.

TABLE 2: Breakdown data of hot swage machine

Months	Reasons for the Breakdown	Number of breakdowns	Time to repair (Hours)	Start time (Hours)	End time (Hours)
Jan.10	Coolant leakage	1	2	7 AM	9 AM
Mar.10	Movement of the table	2	8	3 PM	11 PM
May 10	Movement of the table	2	6	1 PM	7 PM
Aug.10	Oil leakage	1	1	5 PM	6 PM
Sept. 10	Hydraulic oil leakage loose fitting	2	0.5	2 PM	2.30 PM
Nov.10	Heater getting tripped	5	1	9 PM	10 AM
Feb.12	Machine not Switching ON	2	4	4 PM	8 PM
June 12	Oil leakage	1	2	1 PM	3 PM
Sept.12	Die index not working	2	3	9 AM	12 AM
Nov.12	2nd die not moving up to its position	2	4	3 PM	7 PM
April 13	MCB tripped	1	2	7 AM	9 AM
May 13	Die movement not working	2	5	2 AM	7 AM
June 13	Heat not getting ON	4	4	8 AM	12 PM

July 13	Water leakage from power panel	2	2	4 AM	6 AM
Aug.13	Auto cycle interrupted	1	2	6 PM	8 PM
Sept.13	Water leakage	1	2	1 PM	3 PM
Nov.13	Electrical main panel card defective	2	5	2 PM	7 PM
Dec.13	Hydraulic system getting OFF in auto cycle	4	6	8 AM	4 PM
Jan 14	Movement of the table	3	6	12 PM	6 PM
Feb 14	Die index not working	3	6	2 PM	8 PM
Mar. 14	Heat not getting ON	5	6	1 PM	7 PM

From the table: 2 breakdown details due to different component failures were observed and total loss due to these failures were calculated and noticed that there are TWO breakdowns in every month and total of 24 breakdowns per year and cost of each breakdown is Rs 11,300=00, hence total breakdown cost of hot swage machine per year is Rs 2, 71,200=00.

4.2 Process Study of Shot Blasting Machine

Main objective of shot blasting machine is to remove scale and rust in housing component Shot Blasting is a surface treatment process using high velocity steel abrasive. Shot blasting is method through which it is possible to obtain excellent cleaning and surface preparation for secondary finishing operations.

Fig: 2 Shot blast machine

Table 3: Technical specification of Shot Blasting

1	Machine width (mm)	1270
2	Machine depth (mm)	1050
3	Machine height (mm)	1640
4	Blasting chamber width (mm)	740
5	Blasting chamber depth (mm)	760
6	Blasting chamber height (mm)	490
	Blasting gun:	
1	Air nozzle Ø (mm)	2-3
2	Blasting nozzle Ø (mm)	6.5
3	Nozzle material 1	Ceramic/boron carbide
4	Air requirement at 5 bar (m³/h)	13-30
5	Absorption area (m²)	2.5
6	Exhaust power (m³/h)	150
7	Fan power (kW)	0.25

Table 4: Breakdown data of Shot blasting machine

Mont	Breakdowns	No of break down	Repair time	Start time	End time
Mar. 2011	Wheel blade gets broken	2	10	1 PM	10 PM
May 2011	Pipeline blockages	5	7	7 AM	12 PM
June 2011	Power consumption	3	8	6 AM	2 PM
Aug. 2011	Abnormal sound crew conveyor	2	8	3 PM	11 PM
Oct. 2011	Low shots feeding	6	7	9 AM	4 PM
Dec. 2011	Machine body gets leakages	3	4	7 AM	11AM
Jan. 2012	Motor sound abnormal	4	8	6 AM	2 PM
Mar. 2012	Impeller wheel assembly vibration	2	3	8 AM	11 AM
Sept. 2012	Conveyor struck	3	2	6 PM	8 PM
Nov. 2012	Shot feeding struck	2	5	1 PM	5 PM
Feb. 2013	Impeller wheel blade worn out	6	7	3PM	10 PM
July 2013	Improper shots wheel	5	5	6 AM	11 AM
Oct. 2013	Variation of power consumption	3	3	8 AM	11 AM
Nov. 2013	Worn out of bolts	2	2	5 PM	7 PM
Dec.2013	Malfunctioning of drag chain	2	1	10 AM	12 AM

Jan. 2013	Improper function of spout unit	4	3	1 PM	4 PM
Feb. 2014	Locking dome nut worn out	3	1	8 PM	9 PM
Mar. 2014	Metallic Shot feed tube inner diameter is less	5	4	12 PM	4 PM

From the table:4 breakdown details due to different component failures were observed and total loss due to these failures were calculated and noticed that there are FIVE breakdowns in every month and total of 60 breakdowns per year and cost of each breakdown is Rs 500=00, hence total breakdown cost of shot blast machine per year is Rs 30000=00.

V. PROCESS STUDY OF LANDIS THREADING MACHINE

Main objective of Landis threading is to thread the housing spindle .It is an operation for cutting screw threads on metallic parts. In this operation, as shown in Fig:3, the work piece is held in between the two centres, the cutting tool is mounted on the tool post and the carriage is connected to the lead screw with the help of a split nut. The rotation of the lead screw gives the required motion to the carriage relative to the rotation of the work piece. The depth of cut is selected and the tool is made to move parallel to the axis of rotation of the Work piece by means of automatic arrangement. By disengaging split nut or half nut, the Carriages brought back to its initial position to start another cut.

Table 5: Breakdown data of Landis threading machine

SL. NO.	Problems	Number of breakdowns	Time to repair (Hrs)	Start time (Hrs)	End time (Hrs)
1.	Die holders worn	3	6	9 AM	2 PM
2.	Auto lever thread damage	1	4.5	7 PM	11 PM
3.	Chaser chip off	1	2	6 PM	8 PM
4.	Misalignment of die head	5	4	10 AM	2 PM
5.	Worn drive gear	2	6	12 AM	6 PM
6.	Die holders worn out	1	9	1 PM	10 PM
7.	Die heads bent/tilts t	2	5	7 AM	12 PM
8.	Hydraulic power pack not working	1	1	12 PM	1 PM
9.	Dies dull	2	3	6 PM	9 PM
10.	Improper cutting fluid flow	2	1	10 AM	11 AM
11.	Die holders worn	1	6	1 PM	7 PM
12.	Stripping threads	3	5	3 PM	8 PM
13.	Incorrect chaser setting	5	7	10 AM	5 PM
14.	Die head having play in chaser mounting unit	2	4	4 PM	8 PM
15.	Top clamp not rigid	1	0.5	12.30 PM	1 PM
16.	Material hardness variation	1	0.5	3.30 PM	4 PM
17.	Incorrect chaser geometry	6	5	9 AM	2 PM
18.	Chips fusing to dies	2	.30	7.30 AM	8 AM
19.	Teeth on dies worn off	1	.15	11 AM	11.15 AM
20.	Die holders worn out	3	8	1 PM	9 PM

From the Table 5 breakdown details due to different component failures were observed and total loss due to these failures were calculated and noticed that there are SEVEN breakdowns in every month and total of 84 breakdowns per year and cost of each breakdown is Rs 15000=00, hence total breakdown cost of Landis threading machine per year is Rs 12, 06,000=00.

From the above tables breakdown data and reasons for the breakdowns was analyzed and the production loss of the each machine was calculated and listed in the *Table: V* From the *Table: VI* major losses is due to Landis threading machine and hence detailed analysis of the machine and cause for the failure to be rectified to reduce the production cost to the industry.

Table 6: Production losses for different machines

Sl .No.	Machines	Cost per year
1	Hot swage machine	Rs 2,71,200
2	Shot blast machine	Rs 30,000
3	Landis threading machine	Rs 12,06,000

VI. ANALYSIS AND COUNTER MEASURES FOR LANDIS THREADING MACHINE

Data Collection is an important aspect of any type of research study. Inaccurate data collection can impact the Results of a study and ultimately lead to invalid results. Data is essential for investigating the Root Cause of the problem. Data also provides the foundation for:

- Defining the current performance
- Identification of root cause
- Measuring progress
- Verifying effectiveness of solutions

6.1. Goal of the data collection*:*

- Probe the data to determine *what* happened during the occurrence
- Describe *how* it happened
- Understand *why* it happened

6.2 Failure data collection

The following information is Available in maintenance data log books or log sheets and if computerized, data is available in equipment history sheets.

- The data about the causes of breakdown
- Breakdown hours
- Repair time, inspection time and maintenance action taken
- Parts replaced
- The data should also include the failure
- Reasons related to machine, material, process, environment etc.

6.3 Root cause analysis

Root Cause Analysis is a method that is used to address a problem or non-conformance, in order to get to the root cause of the problem. It is used to correct or eliminate the
Cause, and prevent the problem from recurring.

6.3.1 Need for root cause analysis

Root Cause Analysis will disclose:

- Why the incident, failure or breakdown occurred

- How future failures can be eliminated by:
- Changes to procedures
- Changes to operation
- Training of staff
- Design modifications
- Verification that new or rebuilt equipment is free of defects which may shorten life:

Tools of root cause analysis:

6.3.2 Fish bone or Cause and Effect diagram

Diagram: Fishbone analysis is an example of root cause analysis specifically, it‛s a type of cause and effect diagram which helps you to think through causes of a problem thoroughly. Their major benefit is that they push you to consider all possible causes of the problem, rather than just the ones that are most obvious.

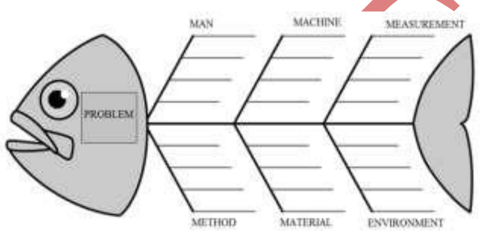

Fig: 4 Fish bone diagram

Causes are usually grouped into major categories to identify these sources of variation. The categories typically include:

- ***People:*** Anyone involved with the process.
- ***Methods:*** How the process is performed and the
- Specific requirements for doing it, such as policies, procedures, rules, regulations and laws.
- ***Machines:*** Any equipment, computers, tools, etc.required to accomplish the job.
- ***Materials***: Raw materials, parts, pens, paper, etc.used to produce the final product.
- ***Measurements:*** Data generated from the process that are used to evaluate its quality.
- ***Environment:*** The conditions, such as location,
  Time, temperature, and culture in which the
  Process operates.

6.3.3. 5-why analysis

The 5-Why method helps to determine the cause-effect Relationships in a problem or a failure event. It can be used whenever the real cause of a problem or situation is not clear. Using the 5-Whys is a simple way to try solving a stated problem without a large detailed investigation requiring many resources. When problems involve human factors this method is the least stressful on participants. It is one of the simplest investigation tools easily completed without statistical analysis. Also known as a Why Tree, it is supposedly a simple form of root cause analysis. By repeatedly asking the question, Why?‛ you peel away layers of issues and symptoms that can lead to the root cause. You start with a statement of the situation and ask why it occurred. You then turn the answer to the first question into a second Why question. The next answer becomes the third Why question and so on. Though this technique is called why –Whys analysis. You may ask more or less Whys before finding the root of a problem.

6.3.4 Benefits of the 5 Whys

- Help identify the root cause of a problem.
- Determine the relationship between different root causes of a problem.
- One of the simplest tools; easy to complete without statistical analysis.

VII. RESULTS AND DISCUSSION

AVAILABILITY:

Availability is the total time of utilization of a machine. Availability is the reciprocal of the difference between the total available hours and total breakdown hours to the total available hours.

$$\text{Availability} = \frac{\text{Total available hours} - \text{Total Breakdown hours}}{\text{Total available hours}} \times 100$$

Mean time between failures: (MTBF)

MTBF is the time between two failures. When failure rate is constant, the mean time between failures is the reciprocal of the constant failure rate or the ratio of the test time to the number of failures.

$$\text{MTBF} = \frac{\text{Total available hours} - \text{break down hours}}{\text{No of breakdowns}} \text{ (in hours)}$$

Mean time to repair: (MTTR)

"Mean Time to Repair" is the average time that it takes to repair something after a failure.

$$\text{MTTR} = \frac{\text{Total break down hours}}{\text{No of breakdowns}} \text{ (in hours)}$$

Table 7: Break down data from January to March 2014

Sl.No.	Month	Total available hours	Total breakdown hours	Utilized hours	Total no. of breakdown
1.	JAN	573	47.30	525.7	7
2.	FEB	529	43.25	485.75	7
3.	MAR	595	39.25	555.5	8

Table 8: Availability, MTBF and MTTR before root cause analysis

Sl.No.	Month	Available	MTBF (Hours)	MTTR (Hours)
1.	January	91%	75:06	06:45
2.	February	91.18 %	69:24	06:10
3.	March	93%	69:24	04:56

VIII. ROOT CAUSE ANALYSIS OF LANDIS THREADING MACHINE

Problem Statement: Main causes of spindle thread damage in Landis threading machine were listed using cause and effect diagram

Using cause effect diagram different possible failures were observed and actions were implemented with the help of Why – Why Analysis some of the failures were listed in the *Table 8* and Corrective counter measures listed in the *Table 9* were implemented to reduce the number of breakdowns.

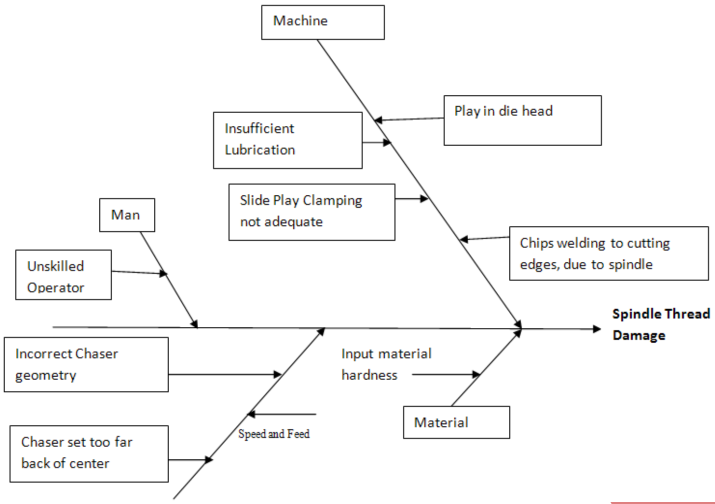

Fig 5: Fish bone diagram for Landis threading machine

Table 9: Why – Why Analysis

Why	Answer	Actions	Results
Top clamp not rigid	Clamping pressure varying from man to man due to manual clamp ,resulting component lifting and observed run out on spindle	Hydraulic swing clamp cylinders provided to both left hand and right hand	Spindle run out observed within .050mm and threads observed free from chattering marks.
Die head having play in chaser mounting unit	Service the die head as per procedure given in machine manual	Servicing done as per procedure and frequency fixed once in every 2 months	Chaser mounting unit play arrested
Improper chaser setting	Chaser set too far back of center	Advance all the chasers of set gradually and equally until chattering disappears	Spindle threads observed free from chattering marks

Table 10: Corrective counter measures

Root Causes	Actions Planned
Input material hardness variation	To maintain the hardness mean and above at forge stage
Incorrect chaser geometry	Chaser grinding in house as per specified angle. Use coolant while grinding the chasers. Do ALCRONA coating for good surface. Finish and tool life after grinding.
Die head servicing	Clear procedure to be made by going through the Landis threading machine manual and calibration to be fixed for once in every 2 months

Table 11: Number of break downs after root cause analysis

Sl.No	Month	Total available hours	Total breakdown hours	Utilized hours	Total no. of breakdown
1.	April	573	21:25	551:42	5
2.	May	595	19:30	575:42	5

Table 12: Availability, MTBF and MTTR after root cause analysis

Sl.No	Month	Availability	MTBF (Hours)	MTTR (Hours)
1.	April	96%	110:21	40:15
2.	May	96.30%	115:08	03:52

***After root cause analysis*:**

From the *Table 12* it is noticed that availability of a machine was increased to 30.28%, mean time between the failures is increased by 74.89% and mean time to repair was decreased by 43.03%. Similarly number of breakdowns per month before implementation of root cause analysis is around 7-8 *Table 7*

After implementation of root cause analysis numbers of breakdowns were minimized and it is noticed that Rs 90,000 to one lakh can be saved per year. Hence preventive maintenance checklist has been suggested to the company in order to reduce maintenance, inventory to enhance production and profit as shown in *Table 13*

Table 13: Preventive Maintenance checklist Suggested

Visual check of mains Electrical Switches, Wiring and/or Conduit (Cracks, broken controls etc.) Arrange for immediate repair of any faults	Daily
Verify all Guards are secure and function correctly (Check latches, locks, fasteners and/or interlocks)	Daily
Ensure workspaces and walk-ways are clear and unobstructed and that no slip-hazards are present	Daily
Confirm availability and condition of Personal Protective Equipment	Daily
Lubricate lightly according to manufacturer's specification	Daily
Conduct close inspection for damage to Switch Gear Test operation of Switch Gear (Proper function of switch controls)	Weekly
Lubricate lightly according to manufacturer's specification	Weekly
Lubricate ways and slides according to manufacturer's specification	Weekly
Conduct close inspection for damage to Switch Gear Test operation of Switch Gear (Proper function of switch controls)	Weekly
Lubricate lightly according to manufacturer's specification	Weekly
Lubricate ways and slides according to manufacturer's specification	Weekly
Check the availability of spare parts i.e. belts cutting tools etc	Quarterly
Lubricate all points in accordance with the manufacturer's specification	Quarterly
Adjust Gibb strips on all slides according to manufacturers specification	Quarterly
Check floor space for oil contamination	Quarterly
Replace suds (if used)	Quarterly
Protect all bare metal surfaces before Term Shutdown	Quarterly
Clear away accumulated scarf and waste from inside and around housings, cabinets etc	Quarterly
Examine drive belts for Flaws & Correct Tension - Adjust if necessary	Quarterly
Check pulleys for Correct Alignment - Adjust if necessary	Quarterly
Check security of all Fixed Guards	Quarterly
Check gear train (Stud gear, change gear etc.) for correct mesh and alignment - Adjust if necessary	Quarterly
Examine bolts used for mounting the motor to the machine. Re-tighten if necessary	Quarterly
Check the security of Machine Mountings to the floor or base block	Quarterly
Remove any raised metal with appropriate reamer	Quarterly
Check condition of line markings defining Operator Zones and Access Walkways	Yearly
Review Safety Operating Procedure and update if necessary	Yearly

IX.CONCLUSIONS

This paper was intending to determine the breakdown analysis of Hot Swage machine, Shot Blasting machine and Landis threading machine. It was identified that breakdowns and production loss in Landis threading machine causes major loss to the company, hence detailed study was carried out to determine availability, MTTR and MTBF. Root cause analysis like why-why analysis, fish bone diagram and corrective counter measures are implemented to identify the actual cause of the breakdown. By implementing average availability of machine is increased by **30.28 %,** the average MTBF is increased by **74.89 % and** MTTR is decreased to **43.03 %.**

This in turn helped to develop and improve a new preventive maintenance schedule and checklist for the machine to enhance production.

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